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BENEFICIATION OF PHOSPHATE ORE FROM NIGER

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MINERAL DRESSING SECTION
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BENEFICIATION OF PHOSPHATE ORE FROM NIGER

by

I.B. Klymowsky* and W.H. Cameron**

SUMMARY

Samples of phosphate ore from the Tapoa area of Niger were received for preliminary beneficiation studies. The samples were primarily composed of two rock types - sandstone and siltstone. The sandstone, assaying 23% P_2O_5, was found to respond very well to flotation and yielded concentrates assaying 34-36% P_2O_5 with recoveries of 67-75% of the phosphate, using a single reverse float. The siltstone, assaying only 5.5% P_2O_5, was most difficult to beneficiate. It was concluded that the siltstone must not be mixed with the bulk of the ore which is sandstone if high grades are to be achieved.

The results obtained justify the expenditure of funds on a more comprehensive laboratory and pilot-plant investigation of the ore. An outline of the various elements to be included in such an investigation is given in the report.

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Introduction

Preliminary testwork was requested by CIDA on samples of phosphate ore from Niger to determine the feasibility of producing a high-grade phosphate concentrate and to provide data for developing a research proposal which could be used in soliciting bids from commercial laboratories for a more comprehensive laboratory/pilot-plant investigation of the ore.

The information made available by CIDA was contained in two technical reports: one by BUREMI of the Republic of Niger,[1] dealing with a geological evaluation of the ore deposit and the second by BRGM of France,[2] dealing with the mineralogy and beneficiation characteristics of samples of the ore.

Exploration in a single area, 2.1 Km^2, north of the Tapoa River in the South-west corner of Niger, indicated reserves of upwards of 100,000,000 tons of ore averaging 23% P_2O_5 within a zone of mineralization averaging 34-m thick. The highest phosphate values within this zone were found associated with sandstone and there were strong indications of more ore to the south and east of the exploration area.

Mineralogical studies conducted by BRGM showed that the ore consisted essentially of apatite and silica and that a grind of minus 100 microns was necessary for liberation. Flotation was recommended as the best approach for concentrating the phosphate. However, the particular flotation approach used, which was a standard double-float, resulted in concentrates

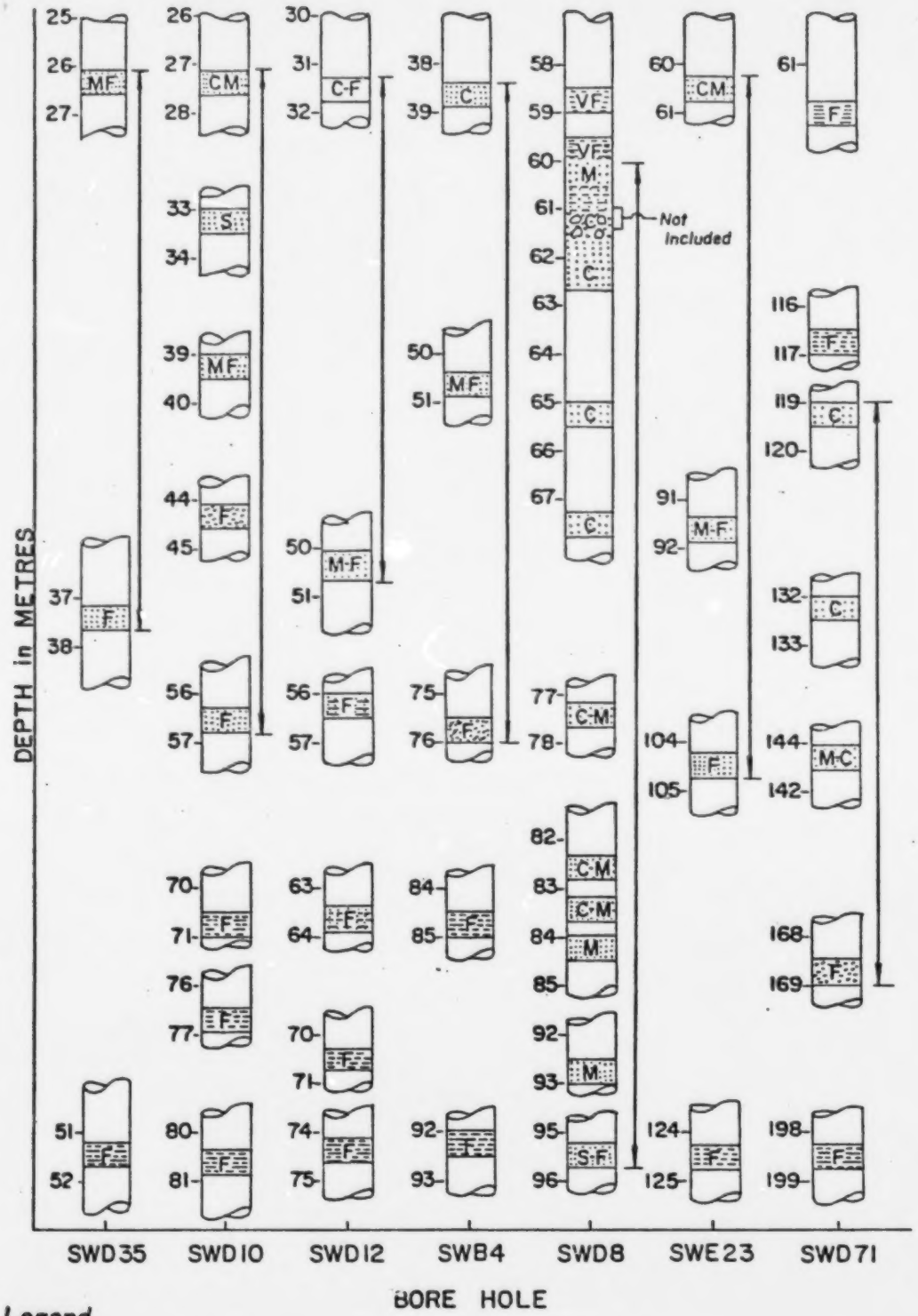

Figure I. STRATIGRAPHIC SECTIONS

EMR, CANMET Ottawa
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assaying no more than 30-33% P_2O_5, and in relatively low recoveries between 35 and 55%. The limited grades were attributed to the presence of numerous silica and pyrite inclusions in the phosphate grains, and the relatively low recoveries to heavy slime losses.

The question that arises is whether these limitations on the grade extend to all of the ore or are peculiar to the type of samples investigated at BRGM.

Samples and Analysis

On October 31, 1977, approximately 20 Kg of samples were received from Naimey, the capital of Niger. The shipment was labelled as representing material from the Tapoa area taken during mission 200. These were all core samples from seven different bore holes as shown in Figure 1.

The cores, numbering 50 in all, were individually packaged in plastic bags and tagged to indicate bore hole, depth from surface, rock type, and grain size of the minerals. Table 1, in the Appendix gives the description and weight of each of the core samples.

Two rock types were prevalent: sandstone, ranging in texture from coarse-grained to fine-grained; and siltstone, containing siltite and argillite and predominantly fine-grained. Nearly all of the siltstone samples were from the bottom of the bore holes, indicating that siltstone forms the base of the ore deposit.

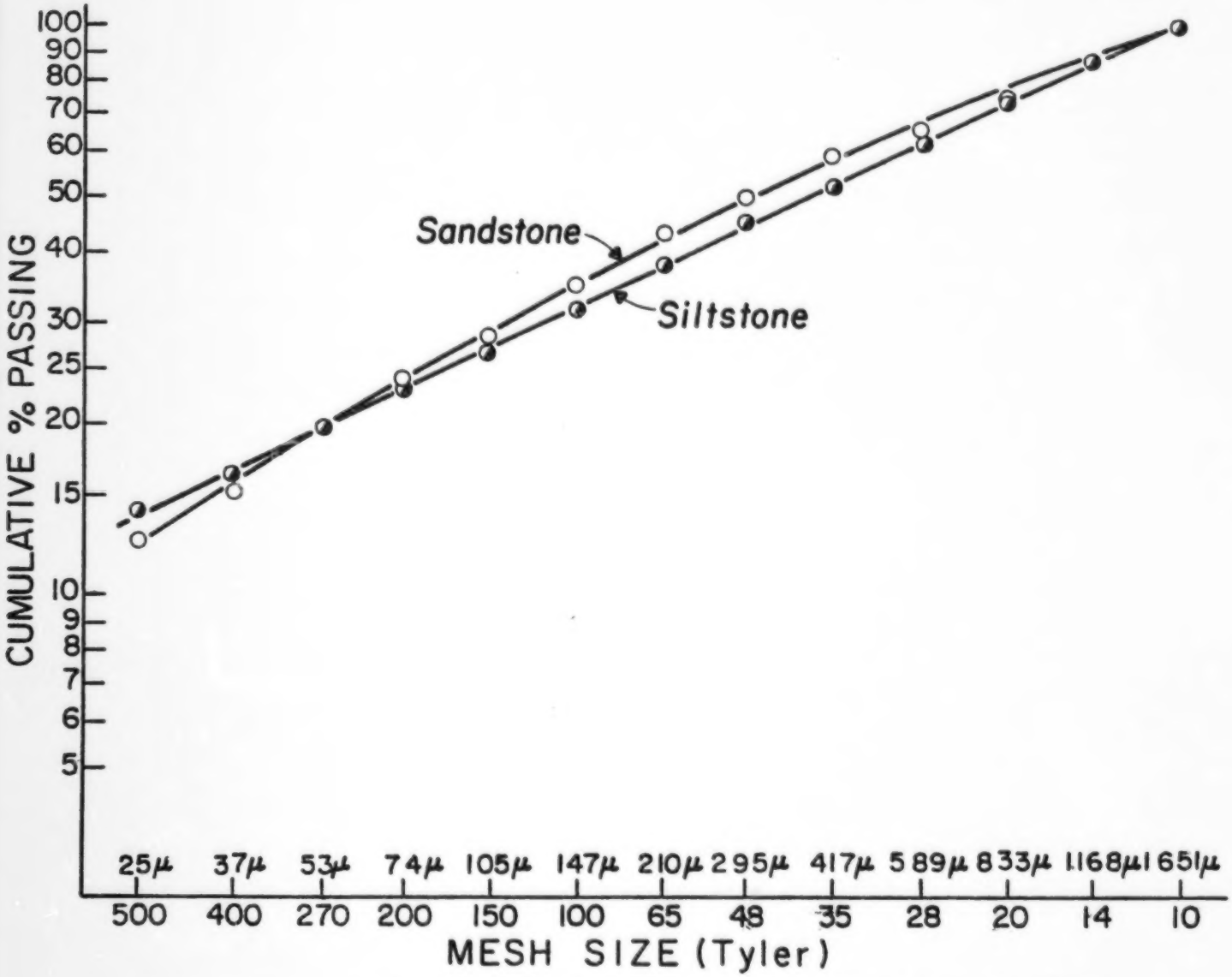

Figure 2. SIZE DISTRIBUTIONS of CRUSHED PRODUCTS

The cores were separated into two lots, according to the prevalent rock type, and each lot was crushed to minus 10-mesh. The size distribution of each of the crushed products is given in Figure 2. There appeared to be no significant difference in the size analysis of the crushed products. Small hand samples of the cores were selected for thin sections before crushing. After crushing, the products were split into 1000-gram samples and bagged.

Head samples of the sandstone and siltstone were analyzed for phosphorus. The sandstone was found to contain 22.82% P_2O_5; the siltstone, 5.48% P_2O_5.

Beneficiation Tests

Seven laboratory beneficiation tests were done on the samples: three flotation tests on samples of the sandstone, one tabling test on the sandstone, and three flotation tests on samples of the siltstone.

For the flotation tests, the samples were stage-ground in a laboratory pebble mill to minus 100 microns and deslimed using a 25-mm Dorr cyclone. The cyclone was operated at a pressure of 30 psi and at a pulp density of 5% solids (by weight) which resulted in a split at approximately 5-10 microns.

The size distributions of the ground products before desliming are given in Figure 3, and after desliming, in Figure 4. The siltstone appears to be slightly finer than the sandstone.

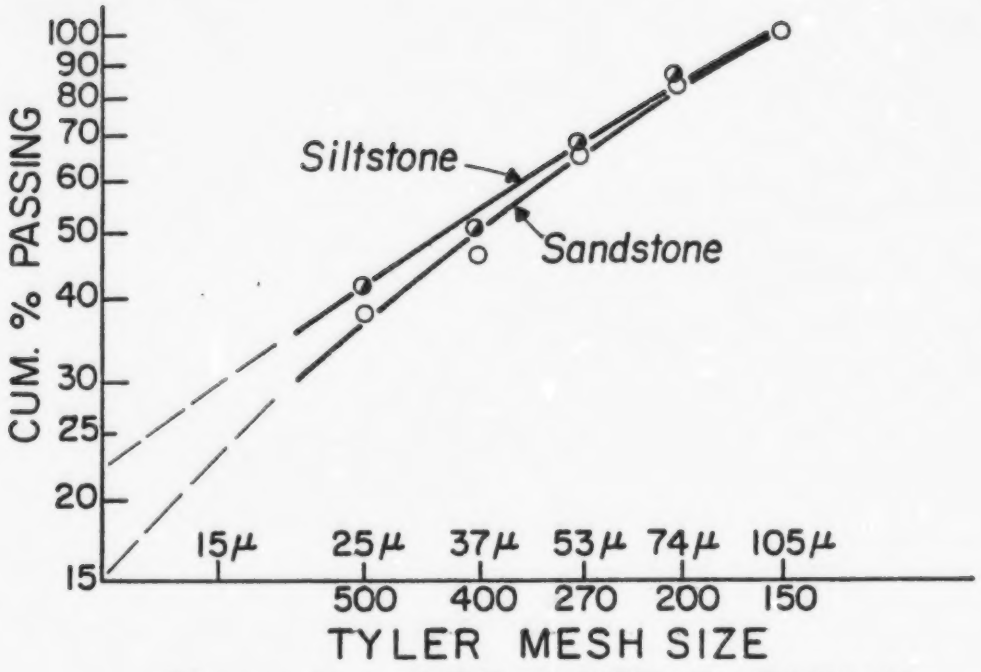

Figure 3. SIZE DISTRIBUTIONS of GROUND PRODUCTS before DESLIMING

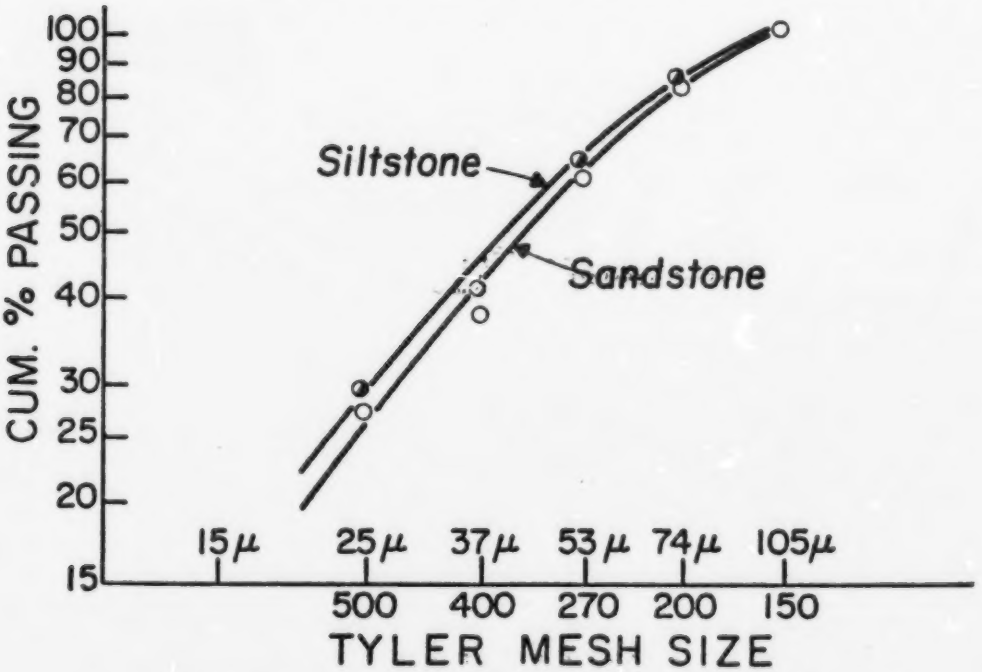

Figure 4. SIZE DISTRIBUTIONS of GROUND PRODUCTS after DESLIMING

The weight of slimes removed from the sandstone was 15.5% of the weight of material treated, and the analysis of these slimes was 22.46% P_2O_5, resulting in no upgrading of the material.

The weight of slimes removed from the siltstone was 23%, and the analysis of these slimes was 3.0% P_2O_5, resulting in a slight upgrading of the feed to flotation.

Three different approaches to the flotation of the sandstone were tried: one, using a standard double-float system; a second, using reverse flotation with one stage of cleaning of the silica froth; and a third, using reverse flotation with two stages of cleaning of the silica froth. Full details of the flotation procedures and results are given in Tables 2, 3 and 4. in the Appendix. Reverse flotation proved by far to be the simplest and most effective approach to concentrating the phosphate in the ore. Concentrates were made assaying 34-36% P_2O_5 (74-78.5% BPL) with recoveries of 67-75%. Higher grade concentrates, assaying over 38.6% P_2O_5 (84% BPL) could be made, but recoveries fell sharply at grades higher than 36% P_2O_5. Figure 5 shows the grade-recovery curves obtained in the flotation tests done on the sandstone. The lowest curve represents the results obtained using a standard double-float system.

The slime losses of 15%, incurred in desliming, were considered tolerable in the light of the fineness of the grind. Tailings assaying as low as 6% P_2O_5 could be produced by employing two stages of cleaning (Test 3).

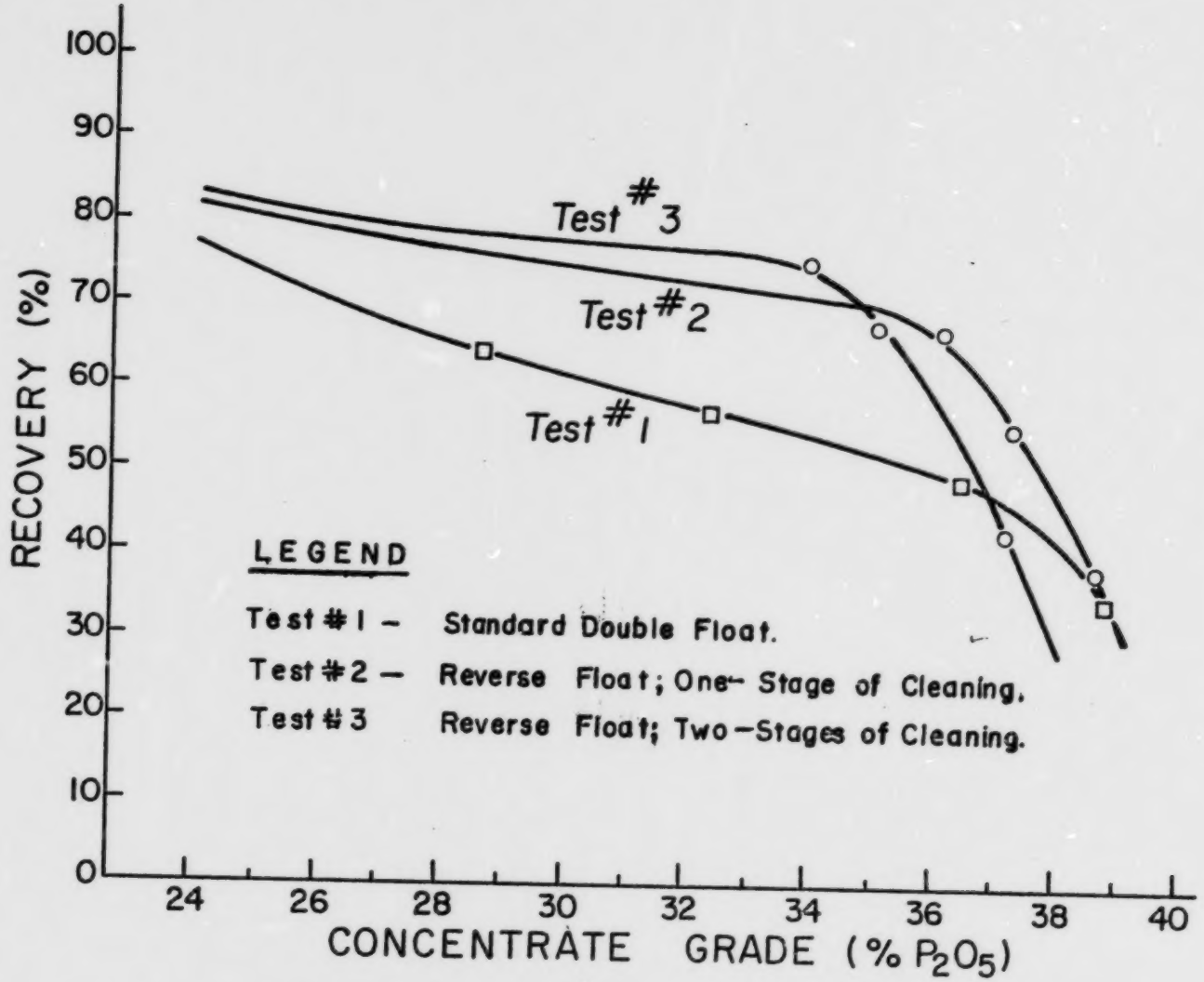

Figure 5. GRADE - RECOVERY CURVES from FLOTATION of the SANDSTONE

Having found no difficulty in obtaining good recoveries and high concentrate grades by flotation, gravity concentration was investigated as a possible alternative to flotation, using a laboratory shaking table. For the tabling test, 4000 grams of sandstone were stage-ground to minus 300 microns and deslimed under the same conditions as described previously for the flotation tests. The weight of slimes removed was 14.4%, which was similar to the weight removed when the sandstone ground to minus 100 microns for flotation, indicating that a certain proportion of slimes is indigenous to the material, and that a coarser grind will not significantly reduce the production of these slimes.

The tabling test was conducted under optimum conditions. The deslimed product was fed to a Deister sand table equipped with a recirculating pump, and when stable conditions were established, a concentrate was removed slightly above the line separating the light and heavy minerals on the table. The tailings were fed a second time and a second concentrate was removed, leaving a tailing which appeared to contain little recoverable phosphate. The results of this test are given in Table 5 in the Appendix. The concentrates produced assayed only 29% P_2O_5, and the tailing, 18.5% P_2O_5, for an overall recovery of 49.3% of the phosphate.

Screen analyses were done on the table concentrates and tailing to evaluate the performance of tabling, and the results are given in Table 6 in the Appendix. The results do not include the slimes since object of evaluation was

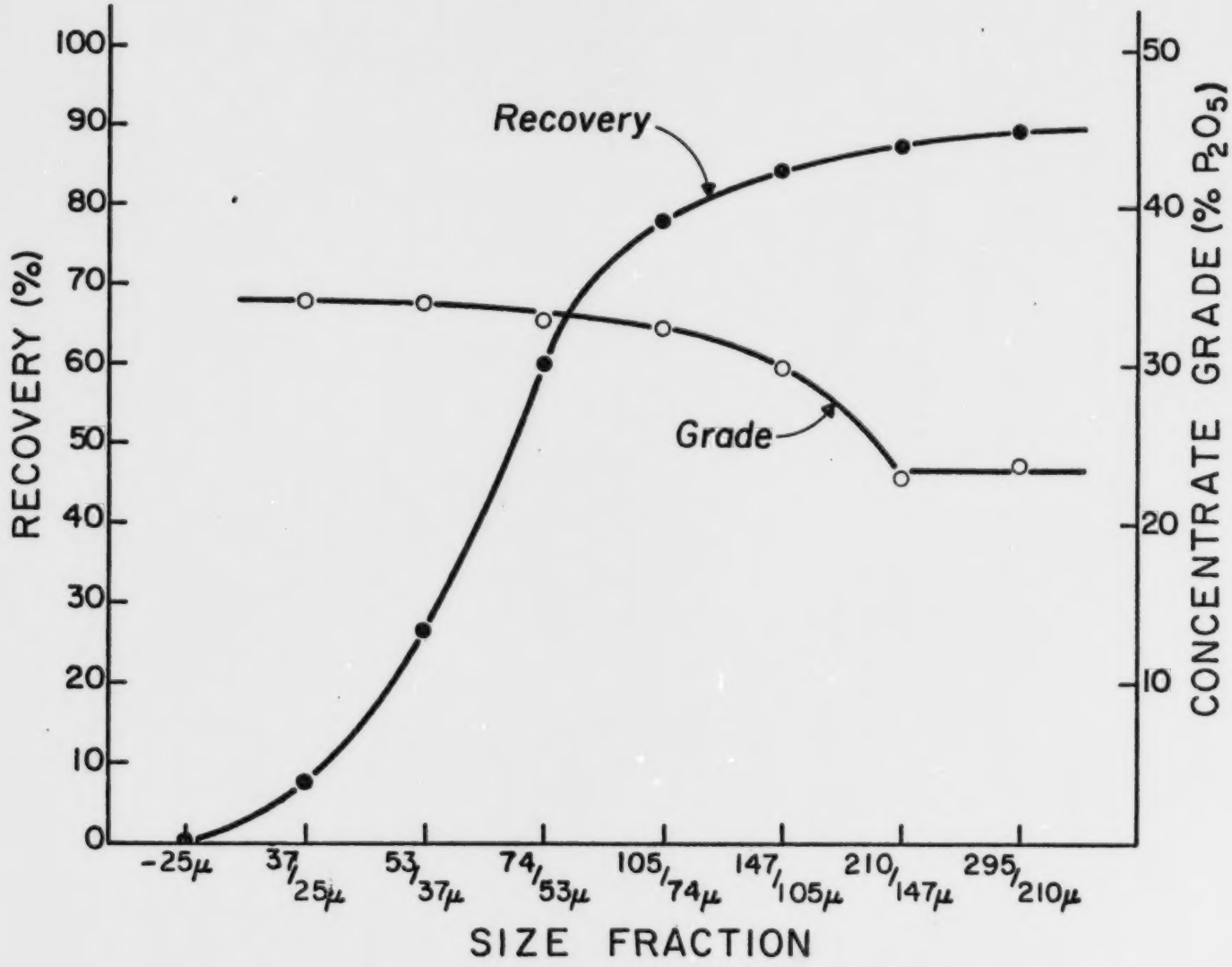

Figure 6. TABLING. RECOVERY and GRADE as FUNCTION of PARTICLE SIZE

the tabling operation. Figure 6 shows recovery and grade as a function of particle size. The recovery falls sharply at sizes finer than 53 microns, and the grade drops from above 30% P_2O_5 at minus 147 microns to 23% P_2O_5 at sizes coarser than 147 microns indicating no significant liberation above this size.

Separation efficiencies were calculated from the screen analyses in Table 6 and are shown in Figure 7. Maximum efficiency of separation occured between 147 and 53 microns.

Flotation tests were done on the low-grade siltstone to determine whether this material would have any detrimental effect on the ore. Three different approaches were investigated: one, using a fatty acid float; a second using reverse flotation and the same combination of reagents as in Test 2; and a third using a di-oleate salt of amine as collector. Full details of the test procedures and results are given in Tables 7,8 and 9. In all cases, the siltstone was found to behave in a very refractory manner. Concentrates assaying more than 12% P_2O_5 could not be made, indicating that the siltstone could have a very detrimental effect if it were combined with the sandstone.

Mineralogy

A brief mineralogical examination was made of the core samples, the crushed products, and some of the flotation products. The results indicated that the sandstone samples were very similar to the samples studied at BRGM. A description of two thin sections is given in the Appendix. The phosphate occurred as pellets, usually green or grayish green, and was

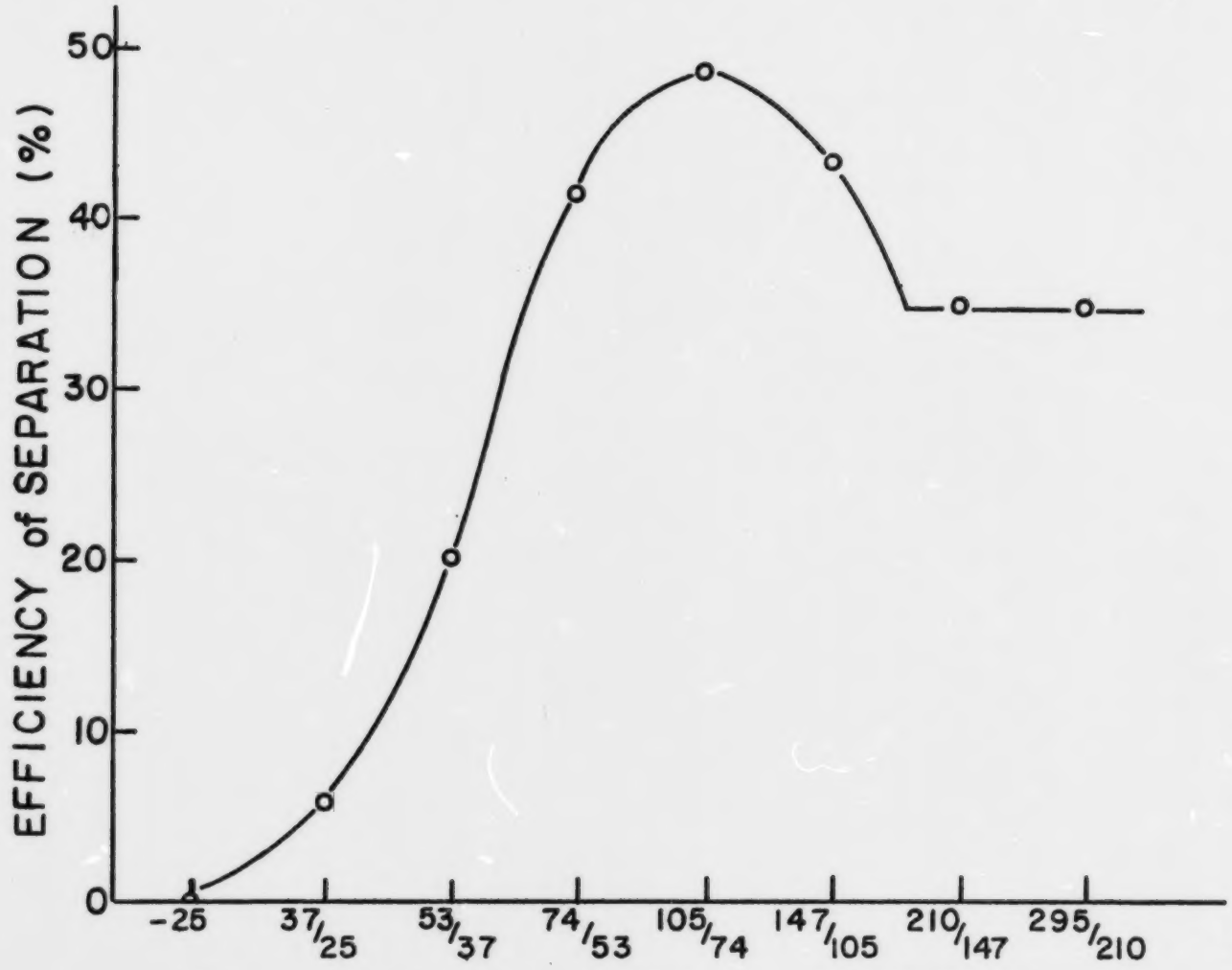

Figure 7. TABLING. SEPARATION EFFICIENCY as FUNCTION of PARTICLE SIZE.

homogeneous with tiny dust-like inclusions. Most phosphate pellets were less than 0.2 mm in size, with some as large as 0.5 mm.

Examination of size fractions of the sandstone crushed to minus 1650 microns indicated that the phosphate was largely liberated at minus 147 microns. A report on this examination is included in the Appendix. The report also notes the presence of small amounts of an aluminum phosphate mineral, which could be troublesome in the production of phosphoric acid.

Four samples of flotation products were examined by XRD analysis: Cyclone Underflow (Flotation Feed) assaying 23.45% P_2O_5, Phosphate Cleaner Concentrate assaying 38.66% P_2O_5, Silica Cleaner Float assaying 10.23% P_2O_5, and Cyclone Overflow (slimes). All samples were from Test 2. The Cyclone Underflow contained apatite and quartz in approximately equal proportions, with very small amounts of calcite and mica. The Phosphate Cleaner Concentrate was essentially pure apatite with very small amounts of quartz and calcite. The Silica Cleaner Float consisted largely of quartz, with lesser amounts of apatite and a trace of mica. The Cyclone Overflow consisted of quartz (50%), apatite (45%), calcite (5%) and very small amounts of mica. Other minor constituents tentatively identified in the samples were dolomite and fluorite. The results indicated that much of the calcite in the feed was removed during desliming. A search for the white particles of aluminum phosphate revealed that the mineral was concentrated in the Phosphate Cleaner Concentrate.

Discussion

Microscopic examination of thin sections of the core samples showed that the phosphate pellets contained tiny dust-

like inclusions, similar to those observed by BRGM, yet these did not appear to prevent the achievement of grades as high as 38.88% P_2O_5. Therefore, the limitations on the grade, as described in the BRGM report, would not appear to extend to the ore body as a whole.

The liberation size of the ore is approximately minus 147 microns, which is a size compatible with certain gravity separation methods. However the difference in the specific gravities of the phosphate and silica minerals is small and difficult to exploit using these separation methods. Therefore gravity separation does not appear to be a very promising approach, leaving flotation as the only viable alternative.

The most effective flotation approach appears to be reverse flotation or flotation of the silica. The largest size at which silica will float readily is approximately 100 microns. There is a certain amount of slimes indigenous to the material which will be produced in grinding. These slimes need to be removed in order to ensure a good flotation response and to overcome any possible problems that might arise from variations in the slime content of the ore. Desliming also provides a means of removing the calcite which tends to be concentrated in the slime fraction. In flotation, the slimes tend to make the froth very stiff, durable, and difficult to handle. It might be possible to devise a method for recovering phosphate from the slimes, using selective flocculation for example, however the additional expense may not be warranted. From the point of view of slime disposal, these appears to be little deleterious material in the slimes of the kind generally

encountered in North American phosphate ores (e.g. montmorillonite), and the slimes may be settled fairly easily.

It is inferred from the BRGM report that the iron and alumina (I&A) content of the concentrates would be less than 3%. XRD analysis of flotation concentrates gave no indication of any problem with iron or alumina minerals, in spite of the fact that an aluminum phosphate species was found in the concentrates.

This report is only a preliminary investigation of beneficiation characteristics of the ore. A more comprehensive laboratory investigation would be necessary to determine:

1) the optimum grind for liberation;
2) the effect of steel grinding media on flotation;
3) the best combination of reagents; i.e., depressants, collectors;
4) the best flotation conditions; e.g., conditioning time, pH, reagent consumption, percent solids, the amount of desliming;
5) the flotation strategy; e.g. open-circuit cleaning vs closed-circuit cleaning, and the number of stages of cleaning.

A more comprehensive laboratory investigation should also include a complete chemical analysis of the feed and products.

Grinding and desliming would appear to be very important in the beneficiation of this ore. These aspects would best be investigated on a pilot-plant scale, as well as aspects of a continuous flotation operation. Aspects recommended for pilot-plant investigation are:

1) the closed-circuit grinding arrangement; e.g., employing a mechanical classifier, cyclones, screens or a combination of cyclones and screens.
2) the desliming system; e.g., employing a single stage of cycloning or two stages of cycloning,
3) water regulation,
4) stages of reagent addition,
5) various flotation circuits,
6) the necessity for thickening or dewatering of middling products,
7) the effect of recycled water,
8) filtration,
9) slimes disposal.

This investigation would lead to the design of a full-scale concentrator.

Conclusions

The following conclusions are drawn from this investigation:

1) High-grade concentrates assaying 34-36% P_2O_5 can readily be produced from the ore as represented by the sandstone core samples received.
2) Recoveries of 67-75% of the phosphate can be achieved by flotation, depending upon the number of stages of cleaning employed and the grade of the final concentrate. Recoveries fall sharply at grades higher than 36% P_2O_5.

3) The best approach to flotation appears to be a simple reverse, or silica, float, rather than the more conventional double float.
4) Desliming of the ore prior to flotation appears necessary to facilitate flotation and to remove the calcite.
5) It is necessary to avoid mixing the ore with siltstone if high-grades are to be achieved. The siltstone is definitely detrimental to the ore. Some form of selective mining may have to be exercised.
6) On the basis of the results achieved in this report, a more comprehensive laboratory and pilot-plant investigation is warranted.

Acknowledgements

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TABLE 1

DESCRIPTION OF CORE SAMPLES

Sample	Core Depth	Prevalent Rock Type	Colour	Grain	Weight	Remarks
1) SWD35 #001	26.10 to 26.40m	Medium & fine sandstone	Greyish	Medium to fine grain	630gms.	Same rock type from 20.75m to 31.30m.
2) SWD35 #002	37.15 to 37.65m	Fine-grained Sandstone	Grey	Fine-grained	55gms.	Same rock type from 26.40 to 45.15m
3) SWD35 #003	51.26 to 51.56m	Siltite-Argillite	Grey to Clear Grey	Fine-grained	620gms.	Same rock type from 47.42 to 60.00m with intermittent sandstone
4) SWD10	27.14 to 27.33m	Sandstone	Dull grey	Medium to Coarse grained	448gms.	For additional laboratory studies
5) SWD10 #00004	33.00 to 33.28m	Speckled sandstone	Grey to black	Medium-fine grained	657gms.	Additional lab. studies
6) SWD10 #00005	39.00 to 39.25m	Medium-fine sandstone	Grey to Black	Medium-fine grained	548gms.	Additional lab. studies
7) SWD10 #00006	44.12 to 44.75m	Massive-fine grained sandstone	Grey to black	Fine-grained	818gms.	Additional lab. studies
8) SWD10 #00008	56.20 to 56.48m	Fine-grained sandstone	Grey to black	Fine-grained	655gms.	Additional lab. studies
9) SWD10 #00010	70.78 to 70.95m	Sandstone siltite and argillite	Dull grey to clear	Heteroge-neous and fine	343gms.	Additional lab. studies

Table 1 (cont'd) Description of Core Samples

Sample	Core Depth	Prevalent Rock Type	Colour	Grain	Weight	Remarks
10) SWD10 #00011	76.86 to 77.00m	Siltite and argillites	Clear grey	Fine-grained	300gms.	Additional lab. studies.
11) SWD10 #00012	80.40 to 80.55m	Siltite and argillites	Grey-black to clear	Fine-grained	278gms.	Additional lab. studies End of hole
12) SWD12 #0001	31.78 to 31.90m	Altered Sandstone	Reddish White	Coarse to fine	200gms.	Same rock type from 30.00 to 34.85m.
13) SWD12 #0002	50.23 to 50.39m	Medium grained Sandstone	Greyish	Medium-fine grained	364gms.	From 34.95 to 47.15m. there is a gap in the sample. Same rock type as from 47.15 to 53.25.
14) SWD12 #0003	56.03 to 56.16m	Fine-grained sandstone and argillite	Dull-grey	Fine-grained	316gms.	Same rock type as from 53.25 to 56.50m.
15) SWD12 #0004	63.68 to 63.90m	Sandstone and Siltite	Dull-grey	Fine-grained	483gms.	Same rock type as from 63.62 to 64.24m.
16) SWD12 #0005	70.32 to 70.67m	Siltite	Greyish	Fine-grained	719gms.	Same rock type as from 69.14 to 73.66m.
17) SWD12 #0006	74.15 to 74.42m	Sandstone siltite and argillite	Dull grey	Fine-grained	688gms	Same rock type as from 76.66 to 80.00 End of drill hole.
18) SWB4 #00002	38.40 to 38.64m	Stratified, banded sandstone	Dull grey to clear	Coarse	479gms.	Same rock type as from 28.10 to 38.80m.
19) SWB4 #00003	53.70 to 53.92m	Medium-fine grained sandstone	Dull grey	Medium	207gms.	Same rock type as from 38.80 to 63.95m.
20) SWB4 #00004	75.51 to 75.80m	Fine-grained massive sandstone	Grey to black	Fine-grained	705gms.	Same rock type as from 63.95 to 76.30m.

Table 1 (cont'd) Description of Core Samples

Sample	Core Depth	Prevalent Rock Type	Colour	Grain	Weight	Remarks
21) SWB4 #00005	84.50 to 84.77m	Siltite	Dull grey	Fine	497gms.	Friable siltite
22) SWB4 #00006	92.00 to 92.29m	Siltite	Grey-black	Fine	547gms.	Same rock type as from 84.00 to 101.85. End of hole.
23) SWD8 #00006	58.55 to 58.72m	Siltite	Grey	Very fine-grained	339gms.	PO_5 mineral from the west of Niger for additional lab. tests
24) SWD8 #00007	58.77 to 58.88m	Siltite	Greyish	Very fine-grained	248gms.	Additional lab. studies
25) SWD8 #00008	58.90 to 59.00m	Siltite	Greyish	Very fine-grained	211gms	Additional lab. studies
26) SWD8 #00017	59.57 to 59.75m	Brecciated Siltite	Grey to clear grey	Very fine-grained	386gms.	PO_5 mineral from West Niger for additional lab. studies.
27) SWD8 #00018	59.75 to 59.88m	Siltite-Argillite	Grey	Very fine-grained	280gms.	PO_5 mineral from West Niger for additional lab. studies.
28) SWD8 #00019	59.88 to 59.98m	Siltite	Greyish	Very fine-grained	188gms.	PO_5 mineral from West Niger for additional lab. studies.
29) SWD8 #00027	61.23 to 61.31m	Siltite and brecciated sandstone	Grey	Coarse	157gms.	Same as sample 00026
30) SWD8 #00032	61.77 to 62.14m	Coarse sandstone	Grey	Coarse	707gms.	PO_5 mineral from West Niger for additional lab. tests.

Table 1 (cont'd) Description of Core Samples

Sample	Core Depth	Prevalent Rock Type	Colour	Grain	Weight	Remarks
31) SWD8 #1	62.38 to 62.68m	Coarse Sandstone	Clear-grey	Coarse	614gms.	
32) SWD8 #2	65.05 to 65.38m	Coarse Sandstone	Clear-grey	Coarse	790gms.	
33) SWD8 #4	67.36 to 67.64m	Coarse Sandstone	Clear-grey	Coarse	605gms.	
34) SWD8 #9	77.27 to 77.51m	Coarse to medium grained Sandstone	Dull grey	Coarse to medium	339gms.	
35) SWD8 #11	82.35 to 82.65m	Coarse to medium Sandstone	Dull grey	Coarse to medium	379gms.	
36) SWD8 #12	83.22 to 83.42m	Coarse to medium Sandstone	Dull grey to clear grey	Coarse to medium	247gms.	
37) SWD8 #13	83.97 to 84.19m	Medium-grained Sandstone	Dull grey	Medium	293gms.	
38) SWD8 #17	92.50 to 92.75m	Medium-grained Sandstone	Dull grey	Medium	389gms.	
39) SWD8 #19	95.25 to 95.48m	Speckled-medium grained Sandstone	Dull grey	Medium	319gms.	
40) SWE23 #0001	60.26 to 60.35m	Coarse to medium Sandstone	Greyish	Medium	275gms.	Pulled between 59.55 and 62.60m.

Table 1 (cont'd) Description of Core Samples

Sample	Core Depth	Prevalent Rock Type	Colour	Grain	Weight	Remarks
41) SWE23 #0002	91.39 to 91.69m	Medium-fine Sandstone	Cinder grey	Medium-fine	407gms.	Sandstone with intermittent argillite
42) SWE23 #0003	104.24-104.53m	Fine Sandstone	Dull grey	Fine	301gms.	Sandstone with intermittent argillite
43) SWE23 #0004	124.28-124.50m	Siltite	Dull black	Fine	272gms.	Siltite (friable)
44) SWD71 #0001	61.76 to 61.91m	Argillite	Grey-green	Fine	318gms.	Same rock type from 59.15 to 64.17m.
45) SWD71 #0002	116.59-116.85m	Siltite	Grey	Fine	212gms.	Same rock type from 85.24 to 117.10m.
46) SWD71 #0003	119.00-119.40m	Sandstone	Grey	Coarse	244gms.	Same rock type from 116.85 to 123.3m.
47) SWD71 #0004	132.00-132.25m.	Coarse Sandstone	Dull grey	Coarse	168gms.	Same rock type from 116.85 to 139.00m.
48) SED71 #0005	144.14-144.45m	Medium-Coarse Sandstone	Dull grey	Medium-Coarse	239.0gms	Passage finishes as a fine Sandstone
49) SWD71 #0006	168.50-168.79m	Fine-grained massive Sandstone	Dull grey	Fine	240.0gms	Contact of fine sandstone and folable siltite at 80.25m.
50) SWD71 #0007	198.32-198.74m	Siltite and argillite	Grey to clear grey	Fine	336.0gms	Same rock type as from 180.25 to 201.82m End of hole
					20,600gms	

Table 2

CANMET FLOTATION TEST REPORT

TEST NO. 1	SAMPLE: Sandstone, Niger; Stage-Ground to -150 Mesh & Deslimed	DATE: Nov. 18, 1977
OBJECT OF TEST:	Produce high-grade phosphate conc. using standard Double-Float system.	CHARGE: 1000-g
		TESTED BY: I.B. Klymowsky

OPERATION	Time min	% Solids	pH	Unit used	Reagents, g per kg of flotation feed. R-765	Pine Oil	Sod. Sil.	H_2SO_4	Na_2CO_3	Dex. 4356	MG.83	MIBC		
Conditioning	5	~50	7.2	1000-gDenver	0.25									
Phos. Rougher Flotn.	3	~30		"		0.04								
Phos. Cleaner Flotn.	3	~30	9.9	"			1.0							
Phos. Re-Cl. Flotn.	3	~30		500-g Denver	-	-	-							
Acid Wash	5	~30	4.2	500-g Denver				36.8						
Filter&Rinse with Water														
Conditioning	5	~30	8.1	500-g Denver					1.5	1.5				
SiO_2 Rougher Flotn.	3	~30		"							0.15	0.02		
SiO_2 Scav. Flotn	3	~20		"							0.075			
Combine SiO_2 Ro+SiO_2 Scav.														
Floats for cleaning:														
SiO_2 Cleaner Flot'n	3	~20		500-g Denver						1.5	0.05	0.02		

PRODUCT	WT %	ANALYSIS % P_2O_5	DISTRIBUTION % P_2O_5
Final Phos. Conc.	19.4	38.88	33.9
SiO_2 Cleaner Tail	10.4	31.93	14.8
Combined Phos. Conc.	29.9*	36.45*	48.7
SiO_2 Cleaner Float	9.1	18.95	7.7
Intermed. Phos. Conc.	39.0*	32.36*	56.4
Phos. Re-Cl. Tail	11.3	15.91	8.0
Phos. Cleaner Tail	28.1	14.67	18.4
Phos. Rougher Tail	6.1	5.96	1.6
Feed to Flotn	84.5*	22.37*	84.4
Cyclone O/F (Slimes)	15.5	22.46	15.6
Total Feed	100.0*	22.38*	100.0

(*Calculated)

REMARKS: Reagents used in Phosphate Flotn were: Cyanamid R-765, an oleic acid mixture, which was prepared by saponifying with NaOH, Pine Oil and soluble sodium silicate; Acid wash was carried out with 100-ml of 2% v/v H_2SO_4
Reagents used in SiO_2 Flotn were: Stien-Hall Dextrin 4356, Ashland Chemicals Mg-83, and Shell MIBC.

Table 3

CANMET FLOTATION TEST REPORT

TEST NO. 2	SAMPLE: Sandstone, Niger; Stage-Ground to -150 Mesh & Deslimed	DATE: Nov. 18, 1977
OBJECT OF TEST:	Produce high-grade phosphate conc. using reverse flotation and one stage of cleaning of the SiO_2 froth.	CHARGE: 1000-g
		TESTED BY: I.B. Klymowsk

OPERATION	Time min	% Solids	pH	Unit used	Reagents, lb per ton								
					NaOH	H_2SO_4	Dex 4356	MG-83	MG-98	A MIBC			
Conditioning	5	~30	10.4	1000-gDenver	0.5		1.5						
SiO_2 Rougher Flotn.	3	~30		"				0.15		0.02			
SiO_2 Rougher Flotn.	5	~30		"				0.05	0.10				
SiO_2 Scav. Flotn.	3	~30	6.5	500-g Denver		0.46	1.0	0.05	0.05	0.01			
Condition SiO Ro.													
Float for Cleaning:	2	~30	8.2	500-g Denver	0.2		0.8						
SiO_2 Cleaner Flotn.	3	~30		"				0.10		0.02			

PRODUCT	WT %	ANALYSIS %								DISTRIBUTION %				
		P_2O_5								P_2O_5				
Final Phos. Conc.	22.5	38.66								37.3				
SiO_2 Scav. Float	11.7	34.22								17.2				
Phos. Rougher Conc.	34.2*	37.13*								54.5				
SiO_2 Cleaner Tail	8.8	32.76								12.4				
Combined Phos. Conc.	43.0*	36.23*								66.9				
SiO_2 Cleaner Float	41.5	10.23								18.2				
Feed to Flotn.	84.5*	23.45*								85.1				
Cyclone O/F (Slimes)	15.5	22.46								14.9				
Total Feed	100.0*	22.45*								100.0				

(*Calculated)

REMARKS:

SiO_2 Scavenger Float was unnecessary

Table 4

CANMET FLOTATION TEST REPORT

TEST NO. 3	SAMPLE: Sandstone, Niger; Stage-Ground to -150 Mesh & Deslimed	DATE: Dec. 16, 1977.
OBJECT OF TEST:	Produce high-grade Phosphate Conc. using reverse flotation and two stages of cleaning of the SiO_2 froth.	CHARGE: 1000-g
		TESTED BY: I.B. Klymowsky

OPERATION	Time min	% Solids	pH	Unit used	Reagents, lb per ton									
						Sod. Sil	Dex. WW82	MG-83	MG-70A	MG-98A	MIBC			
Conditioning	5	~30	8.9	1000-gDenver		0.50	1.0							
SiO_2 Rougher Flotn.	2	~30		"				0.10			0.02			
"	2	~30		"					0.05					
SiO_2 Scav. Flotn	3	~30		500-g Denver			1.0			0.10	0.02			
"	3	~30		500-g Denver					0.05		0.01			
Conditioning SiO_2 Ro														
Float for Cleaning	2	~30		500-g Denver			1.0							
SiO_2 Cleaner Flotn.	3	~30		"						0.5				
SiO_2 Re-Cl. Flotn.	3	~30		"			-	-	-	-	-			

PRODUCT	WT %	ANALYSIS %							DISTRIBUTION %				
		P_2O_5							P_2O_5				
Final Phos. Conc.	25.6	37.30							42.5				
SiO_2 Scav. Float	17.0	31.82							24.1				
Phos. Rougher Conc.	42.6*	35.11*							66.6				
Comb. SiO_2 Cl. Tails	7.0	27.30							8.5				
Comb. Phos. Conc.	49.6*	34.01*							75.1				
SiO_2 Re-Cl. Float	34.9	6.01							9.4				
Feed to Flotn.	84.5*	22.45*							84.5				
Cyclone O/F (Slimes)	15.5	22.46							15.5				
Total Feed	100.0	22.45*							100.0				

(*Calculated)

REMARKS: MG-70A was a cheaper, yet more powerful collector than MG-83. SiO_2 Scavenger Float was unnecessary.

Table 5

Table Test Results

Product	Wt%	%P_2O_5	Distn %
1st. Table Conc.	28.6	29.36	49.3
2nd. Table Conc.	10.4	29.37	
2nd. Table Tail	46.8	18.55	37.3
Cyclone O/F (Slimes)	14.2	21.99	14.4
Total Feed	100.0	23.25	100.0

Table 6

Screen Analysis of Table Products

Size Fraction (microns)	Table Feed			Table Concentrates			Table Tailing			Recoveries % obtained in Concentrates		Efficiency of Separation
	Analysis,%			Analysis,%			Analysis,%					
	Wt%	P_2O_5	SiO_2	Wt%	P_2O_5	SiO_2	Wt%	P_2O_5	SiO_2	P_2O_5	SiO_2	%
295/210	6.88	18.90	52.76*	4.89	23.74	40.65*	1.99	7.08	82.30*	89.3	54.9	34.4
210/147	18.19	17.87	55.32*	12.44	22.89	42.77*	5.75	7.02	82.45*	87.6	52.9	34.7
147/105	17.60	23.52	41.19*	11.74	29.82	25.45*	5.86	10.94	72.65*	84.6	41.3	43.3
105/74	14.67	24.40	38.99*	8.67	32.21	19.47*	6.00	13.09	67.27*	78.0	29.5	48.5
74/53	11.94	23.12	42.21*	5.07	32.54	18.65*	6.87	16.19	59.52*	59.8	18.8	41.0
53/37	13.09	23.38	41.56*	2.41	33.82	15.45*	10.68	20.93	47.67*	26.6	6.8	19.8
37/25	5.45	21.47	46.32*	0.27	33.82	15.45*	5.18	20.93	47.67*	7.8	1.7	6.1
-25	12.18	24.13	39.67*	-	-	-	12.18	24.13	39.67*	0.0	0.0	0.0
Total	100.0	22.20	44.50*	45.49	28.27	29.32*	54.51	17.14	57.15*	57.9	30.0	27.9

(*Calculated Analysis assuming the samples contain only apatite and silica, and the apatite assays 40% P_2O_5).

Head Analysis 22.82% P_2O_5

Table 7

CANMET FLOTATION TEST REPORT

TEST NO. 4 | SAMPLE: Siltstone, Niger; Stage-Ground to -150 Mesh & Deslimed. | DATE: Nov. 30, 1977.

OBJECT OF TEST: Determine the behaviour of this low-grade material in fathy acid flotation. | CHARGE: 1000-g | TESTED BY: I.B. Klymowsky

OPERATION	Time min	% Solids	pH	Unit used	Reagents. Na_2CO_3	R-765	Pine Oil	Sod. Silicate
Conditioning	5	~50	8.9	1000-gDenver	0.5	0.15		
Phos. Rougher Flotn.	3	~30		"			0.04	
Phos. Rougher Flotn.	3	~30		"		0.075		
Phos. Rougher Flotn.	3	~30		"		0.10	0.04	
Phos. Scav. Flot'n.	3	~30	8.7	500-g Denver	0.25	0.15	0.04	
Combined Ro. and Scav. Float for Cleaning:								
Phos. Cleaner Flot'n.	5	~30	9.6	500-g Denver		0.15	0.02	1.0

PRODUCT	WT %	ANALYSIS % P_2O_5	DISTRIBUTION % P_2O_5
Phos. Cleaner Conc.	34.5	11.93	73.6
Phos. Cleaner Tail	20.2	2.15	7.7
Phos. Scav. Tail	22.3	1.61	6.4
Feed to Flotn.	77.0*	6.38*	87.7
	23.0	2.99	12.3
Total Feed	100.0	5.60*	100.0

(*Calculated)

REMARKS: Phosphate difficult to float selectively.

Table 8

CANMET FLOTATION TEST REPORT

TEST NO. 5 | SAMPLE: Siltstone, Niger; Stage-Ground to -150 Mesh & Deslimed | DATE: Nov. 30, 1977.

CHARGE: 1000-g

TESTED BY: I.B. Klymowsky

OBJECT OF TEST: Determine the behaviour of this low-grade material in reverse flotation.

OPERATION	Time min	% Solids	pH	Unit used	Reagents, g per Kg of Flotation Feed				
					NaOH	Dex. ~~4356~~	MG-83	MG-98A	MIBC
Conditioning	5	~30	9.8	1000-gDenver	0.5	1.5			
SiO_2 Rougher Flotn.	3	~30		"				0.15	0.02
SiO_2 Rougher Flotn.	3	~30		"			0.15		
SiO_2 Rougher Flotn.	3	~30		"			0.10		
SiO_2 Rougher Flotn.	3	~30		"			0.10		
SiO_2 Scav. Flotn.	3	~30		"			0.05	0.05	0.02
Sec. SiO_2 Scav. Flotn	3	~30	10.0	"	0.2		0.075	0.025	

PRODUCT	WT %	ANALYSIS % P_2O_5	DISTRIBUTION % P_2O_5
Final Phos. Conc.	38.9	10.48	64.6
Sec. SiO_2 Scav. Float	3.3	9.46	4.9
SiO_2 Scav. Float	16.8	4.41	11.7
SiO_2 Rougher Float	18.0	2.77	7.9
Feed to Flotn.	77.0*	7.31*	89.1
Cyclone O/F (Slimes)	23.0	2.99	10.9
Total Feed	100.0*	6.32*	100.0

(*Calculated)

REMARKS:

SiO_2 difficult to float selectively.

Table 9

CANMET FLOTATION TEST REPORT

TEST NO. 6 | SAMPLE: Siltstone, Niger; Stage-Ground to -150 Mesh & Deslimed | DATE: Dec. 2, 1977

OBJECT OF TEST: To determine the response of the SiO_2 to a compound amine-oleic acid collector such as Armac TDO. | CHARGE: 1000-g | TESTED BY: I.B. Klymowsky

OPERATION	Time min	% Solids	pH	Unit used	Reagents, g per Kg of Flotation Feed									
					NaOH	Dex. 4356	TDO	M6-83	MG-98A	MIBC				
Conditioning	5	~30	9.9	1000-gDenver	0.5		0.15							
Rougher Flotn.	3	~30		"						0.02				
Scav. Flotn.	3	~30		"			0.15	0.10						
Sec. Scav. Flotn.	3	~30		"			0.15		0.10					
Combine Ro & Scav.														
Floats for Cleaning:														
Cleaner Flotn.	3	~30	9.0	500-g Denver		1.0		0.05	0.05					

PRODUCT	WT %	ANALYSIS %	DISTRIBUTION %
		P_2O_5	P_2O_5
Final Phos. Conc.	25.5	10.92	
Sec. Scav. Float	19.5	6.25	47.3
SiO_2 Cleaner Tail	14.4	4.57	20.8
SiO_2 Cleaner Float	17.6	2.97	11.2
			8.9
Feed to Flotn	77.0*	6.73*	88.2
Cyclone O/F (Slimes)	23.0	2.99	11.8
Total Feed	100.0*	5.87*	100.0

(*Calculated)

REMARKS: Response to TDO is poor.

MEMORANDUM

GOVERNMENT OF CANADA

NOTE DE SERVICE

GOUVERNEMENT DU CANADA

FROM / DE
R.M. Buchanan
Head
Ore Mineralogy Section, IML

TO / À
I.B. Klymowsky
Assistant Head
Mineral Dressing Section, OPL

SECURITY - CLASSIFICATION - DE SÉCURITÉ

OUR FILE — NOTRE RÉFÉRENCE

YOUR FILE — VOTRE RÉFÉRENCE

DATE
December 20, 1977

SUBJECT / SUJET Microscopic Examination of Two Specimens of Niger Phosphate

"No. 00027, SWD8-61.23-61.31 m" (LS-39-77)

In thin section the rock shows indistinct layers and prominent cross-bedding with some lightly iron-stained areas. There are two principal components, phosphate and quartz. The phosphate occurs in distinct, well rounded pellets, usually ovoid in shape and so fine-grained as to appear isotropic. They are usually green or greyish green, and homogeneous, with tiny dust-like inclusions. Only rarely is part of the pellet in the form of thin concentric layers and no nuclei of quartz or fossil fragments were observed. Quartz occurs as clear, well round or sub-angular grains and as fine-grained, cherty cement for both principal constituents. The proportion and grain size of phosphate and quartz varies considerably with the quartz generally larger than associated phosphate pellets. Most phosphate pellets are less than 0.2 mm in size, with some as large as 0.5 mm.

"No. 0006, SWD12-74.15-74.42 m" (LS-38-77)

The specimen is a distinctly layered rock, varying in colour from light grey to black. Microscopically, three components were observed, phosphate, quartz and clay (extremely fine grained material that appears very dark or opaque in thin section). Most layers are predominantly clay with scattered grains of quartz and pellets of phosphate. Some thicker layers are coarser and comprise aggregates of phosphate pellets and quartz grains no more than about 0.2 mm in size. Cement in the coarser layers is cherty quartz. Most of the coarser layers are less than 1.0 mm thick.

R.M. Buchanan

/mj

Project No. 3.1.3.9.01
Lab. No. IM-MIN-1874

Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

CANMET
Canada Centre for Mineral and Energy Technology
Centre canadien de la technologie des minéraux et de l'énergie

A STUDY OF THE LIBERATION OF MINERAL PHASES DURING PROCESSING OF PHOSPHATE ROCK FROM NIGER

J.A. SOLES AND W.A. MACDONALD

ORE MINERALOGY SECTION
INDUSTRIAL MINERALS LABORATORY

FEBRUARY 1978

Project No. MRP-3.1.3.9.01
Cost Recovery Work; Federal Departments and Agencies

This report relates essentially to the samples as received.

MINERALS RESEARCH PROGRAM

MINERAL SCIENCES LABORATORIES
REPORT MRP/MSL 78-37 (TR)

A STUDY OF THE LIBERATION OF MINERAL PHASES DURING PROCESSING OF PHOSPHATE ROCK FROM NIGER

by

J.A. Soles* and W.A. MacDonald**

* * *

INTRODUCTION

Samples of different screen fractions of a phosphatic sandstone from the Republic of Niger, prepared for flotation processing by the Mineral Dressing Section of the Ore Processing Laboratory, were examined under the stereomicroscope and particle counts were made to determine the size range at which the phosphate and associated minerals were mostly liberated. In addition, an unknown contaminant was analyzed.

EXPERIMENTAL RESULTS

The mineralogy and texture of the rock has been described previously[1] from a study of thin sections and by X-ray analysis. The principal constituents of the sample are quartz and apatite. Comminution has freed phosphate nodules and the frosted quartz grains along weak grain boundaries, but some of the fragments contain remnants of both phases in each other, even below the 200-mesh size. The photomicrographs in Figure 1 show the mineralogy

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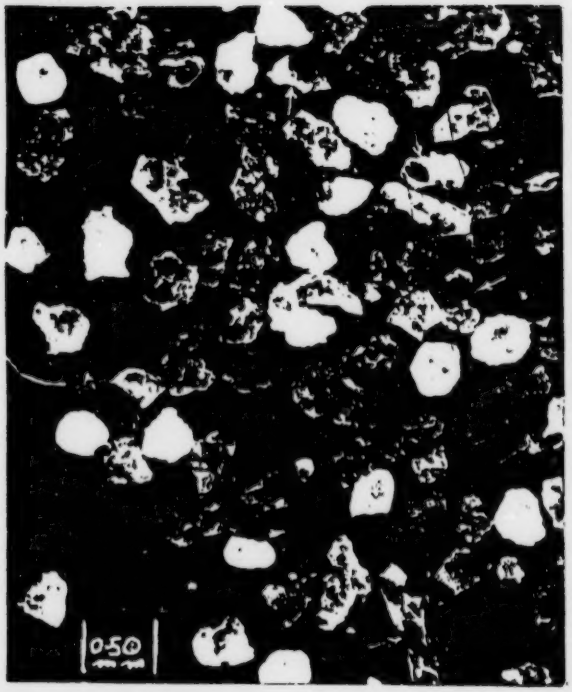
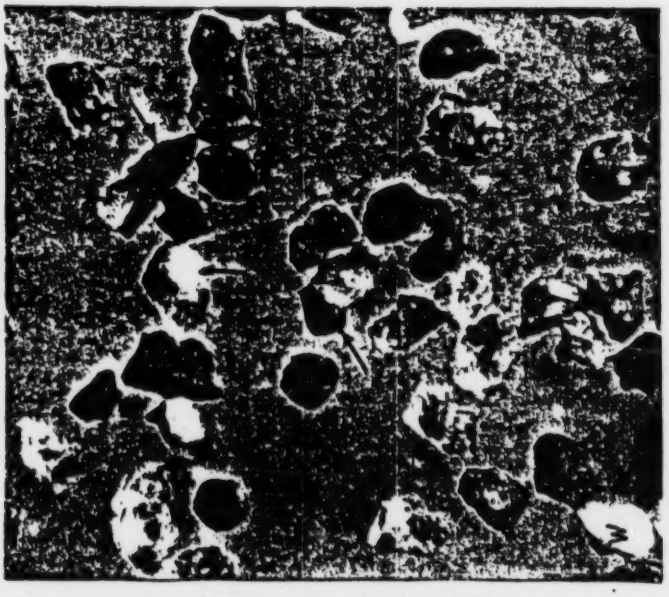
*Research Scientist and **Technologist, Mineral Sciences Laboratories, CANMET, Dept. of Energy, Mines & Resources, Ottawa, Canada.



A. Tyler mesh (-48+65)

B. Tyler mesh (-65+100)



C. Tyler mesh (-150+200)

Figure 1. Photomicrographs of particles in different screen fractions of crushed phosphatic sandstone from Niger. Quartz is translucent white, phosphate nodules and fragments are light to dark grey, unknown is white (W). Locked quartz + phosphate particles are arrowed (↗).

of particles in different size fractions, and the histogram in Figure 2 gives the results of particle count analyses of phases in four of the fractions.

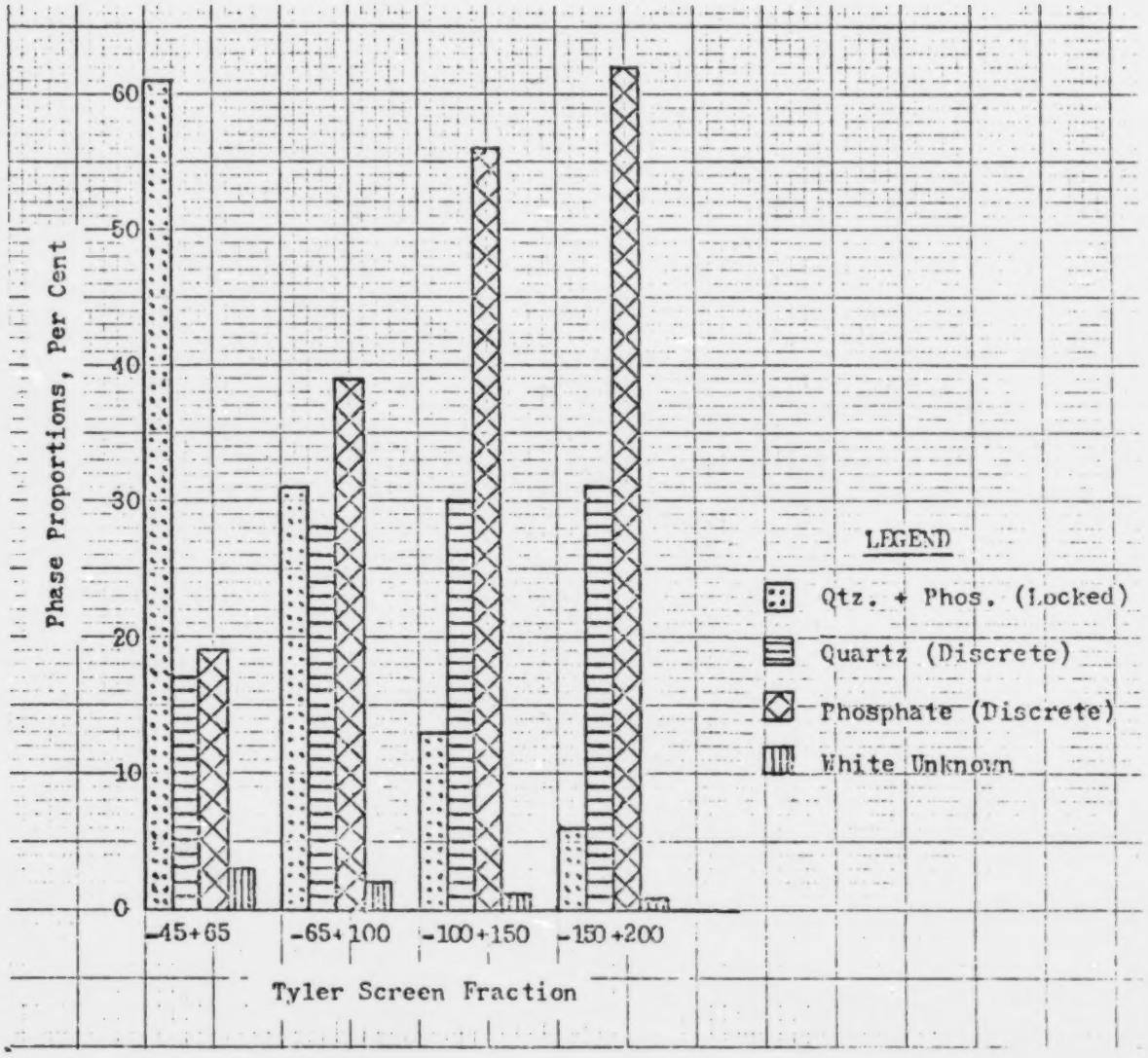


Figure 2. Mineralogical analyses of sized fractions of Niger phosphatic sandstone.

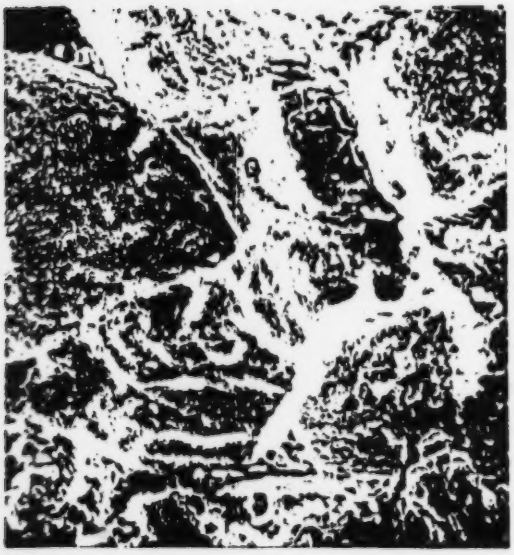
Selected grains of slightly friable white particles, which concentrated in the phosphate sink product up to a maximum of 6 per cent by volume, were examined. Quartz is abundant within the particles as rounded grains or anhedral masses, but the aphanitic matrix surrounding it is mixture of phases. Petrographic study of fragments showed that isotropic material (Refractive Index = 1.51) and an anisotropic mineral (R.I. = 1.58) were present. An X-ray energy dispersive spectrum (Figs. 3, 4) obtained of the matrix with a scanning electron microscope* revealed that aluminum and phosphorus are the principal constituent elements, which suggests that at least one phase is an aluminum phosphate. A Guinier-deWulff X-ray diffraction pattern revealed that variscite ($AlPO_4.2H_2O$) was probably present, but other lines could not be identified.

CONCLUSIONS

This study indicates that crushing the Niger phosphatic sandstone to minus 100 Tyler mesh (<150 μm) should free sufficient phosphate to obtain a good concentrate, with an acceptable recovery. Deleterious amounts of aluminum should not appear in the phosphate fraction if the white fragments were the only source of Al; however, chemical analyses of the concentrate fractions are required to confirm that the content is within tolerable limits, that is, <3% ($Al_2O_3 + Fe_2O_3$)[2].

*Cambridge Instruments Mk IIA Stereoscan, with Ortec 6200 Analyzer.

A. Magnification X200



B. Magnification X500

Figure 3. Scanning electron photomicrographs of particle of the white material observed in the Niger phosphatic sandstone, showing nodular to fibrous or structureless forms. Quartz occurs within the particles both as detrital grains and as interstitial cherty masses (Q).

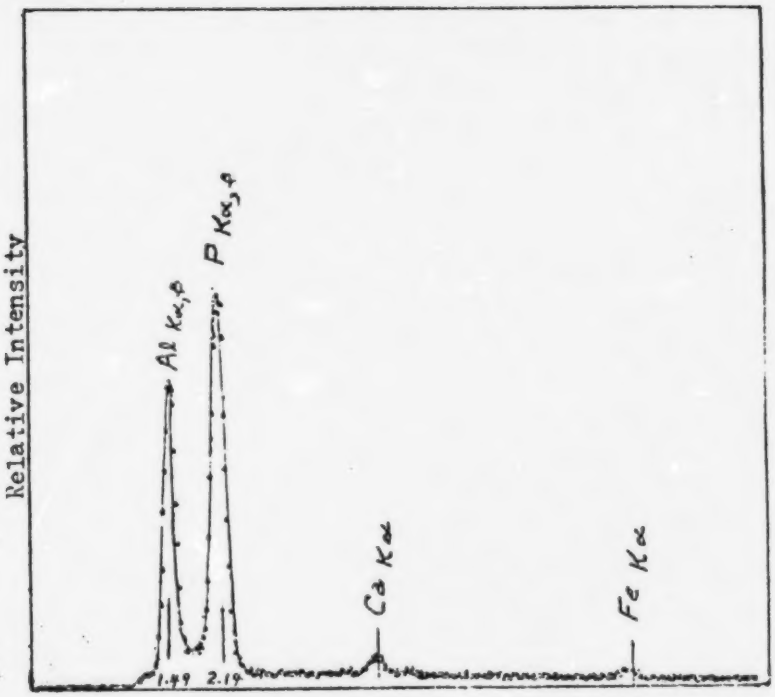


Figure 4. Scanning electron microscope X-ray energy dispersive spectrum of a quartz-free area of the particle shown in Fig. 3. The principal phase is an aluminum-phosphorus compound.

REFERENCES

1. Buchanan, R.M. "Microscopic examination of two specimens of Niger phosphate"; Memorandum, p 3, Dec. 20; 1977.

2. Kouloheris, A.P. "Solving problems in chemical processing of low quality phosphate rock"; Eng. & Mining Journal, v. 178, No. 9, pp 104-108.

/bb